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RESEARCH MEMORANDUM

for the

U. S. Air Force

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SOME EFFECTS OF AEROELASTICITY ON THE ROLLING
EFFECTIVENESS OF A 10-PERCENT-SCALE MODEL
OF THE McDONNELL F-101A AIRPLANE WING
AT MACH NUMBERS FROM 0.5 TO 1.2

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SOME EFFECTS OF AEROELASTICITY ON THE ROLLING EFFECTIVENESS OF A 10-PERCENT-SCALE MODEL OF THE McDONNELL F-101A AIRPLANE WING AT MACH NUMBERS FROM 0.5 TO 1.2

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SUMMARY

At the request of the U. S. Air Force the Langley Pilotless Aircraft Research Division has made an investigation to determine some effects of aeroelasticity on the rolling effectiveness of a 10-percent-scale model of the McDonnell F-101A airplane wing. Tests were made by means of rocket-propelled models in free flight over a range of Mach numbers from 0.5 to 1.2. Results of the investigation indicate that the aeroelastic losses in rolling effectiveness of a model with wing stiffness comparable to that of the full-scale F-101A airplane varied from about 6 percent at 35,000 feet to about 27 percent at sea level at a Mach number of 0.5 and from about 20 percent at 35,000 feet to about 84 percent at sea level at a Mach number of 1.2.

INTRODUCTION

At the request of the U. S. Air Force the Langley Pilotless Aircraft Research Division has made an investigation to determine some effects of aeroelasticity on the rolling effectiveness of a 10-percent-scale model of the McDonnell F-101A airplane wing. Models having very stiff wings and models having wings which approximated the scale stiffness characteristics of the full-scale F-101A airplane were tested with aileron deflections of 15° and 25°. The tests were made on rocket-propelled models in free flight over a Mach number range from 0.5 to 1.2.

SYMBOLS

b	wing span, ft
M	Mach number
m	static test couple applied at $0.945 \frac{b}{2}$ in a plane parallel to the model center line and perpendicular to the wing chord plane, in-lb
P	test load applied at station 26.38 measured along the 48.07-percent-chord line, lb
p	rolling velocity, radians/sec
q	dynamic pressure, lb/sq ft
R	Reynolds number, based on wing mean geometric chord of 0.928 ft
V	model flight-path velocity, ft/sec
$\frac{pb}{2V}$	wing tip helix angle, radians
δ_a	deflection of each aileron measured in a plane perpendicular to the aileron hinge line, deg
δ	deflection of 48.07-percent-chord line of wing resulting from P, in.
θ	angle of twist in a plane parallel to the model center line and perpendicular to the wing chord plane, radians
ϕ	fraction of rigid-wing rolling effectiveness retained by the flexible wing
$\frac{\theta}{m}$	torsional-stiffness parameter, radians/in-lb
$\frac{\delta}{P}$	flexural-stiffness parameter, in./lb
$1 - \phi$	fractional loss in rolling effectiveness

MODELS AND TESTS

The models tested were provided by the McDonnell Aircraft Corporation and consisted of 10-percent-scale reproductions of the F-101A airplane wing mounted on pointed cylindrical bodies 9 inches in diameter with a cruciform arrangement of delta tail fins. The basic model wings (not including wing fillet area) had an aspect ratio of 4.281 and a taper ratio of 0.284 and were swept back 36.84° at the 20-percent-chord line. A photograph of one of the models and a dimensioned sketch are shown in figures 1 and 2.

One of the models had a wing of very stiff construction (25° aileron deflection) and two of the models had wings which approximated the scaled-down stiffness characteristics of the full-scale F-101A airplane wing (15° and 25° aileron deflections). The stiffness characteristics of the model wings are compared with the scaled-down stiffness characteristics of the full-scale airplane wing (ref. 1) in figure 3.

The models were propelled to a Mach number of about 1.2 by a rocket propulsion system. Test data were recorded during a period of free flight following burnout of the propulsion rockets. Rolling velocity was obtained by means of spinsondes, and model flight-path velocity and space coordinates were obtained by means of radar. Atmospheric data were obtained from radiosondes and were used with the test data to obtain the variation of $pb/2V$ with Mach number. The range of Reynolds numbers encountered during the tests is given in figure 4.

ACCURACY

The test data are estimated to be accurate within the following limits:

	Subsonic	Supersonic
$\frac{pb}{2V}$	± 0.010	± 0.005
M	± 0.010	± 0.010

The $pb/2V$ data have not been corrected for the effects of rolling moment of inertia. Reference 2 shows this correction to be small except in the transonic region, where rolling accelerations become large. For this reason, the accuracy limits in the transonic region $(0.88 < M < 1.00)$ are about ± 20 percent.

RESULTS AND DISCUSSION

The variation of the rolling effectiveness parameter $pb/2V$ with Mach number is shown at model test altitudes in figure 5. These $pb/2V$ values have been corrected by the method of reference 3 for the small wing and tail incidence angles resulting from construction tolerances. Included in figure 5 is the rigid-wing rolling effectiveness which was estimated by cross plotting the data for 25° aileron deflection against θ/m and making a straight line extrapolation to $\theta/m = 0$.

Flexible-wing rolling effectiveness at sea level and 35,000 feet was estimated from the data for 25° aileron deflection by assuming that the loss in rolling effectiveness $1 - \phi$ is proportional to the dynamic pressure q. The variation of $1 - \phi$ and q with Mach number for the flexible-wing model with 25° aileron deflection at test altitudes is shown in figure 6. Estimated flexible-wing rolling effectiveness at sea level and 35,000 feet is compared with estimated rigid-wing rolling effectiveness in figure 7. Figure 7 shows that the loss in rolling effectiveness due to aeroelasticity varied from about 6 percent at 35,000 feet to about 27 percent at sea level at a Mach number of 0.5 and from about 20 percent at 35,000 feet to about 84 percent at sea level at a Mach number of 1.2.

CONCLUSION

From an investigation to determine some effects of aeroelasticity on the rolling effectiveness of a 10-percent-scale model of the McDonnell F-101A airplane wing the following conclusion may be drawn:

The loss in rolling effectiveness due to aeroelasticity varied from about 6 percent at 35,000 feet to about 27 percent at sea level at a Mach number of 0.5 and from about 20 percent at 35,000 feet to about 84 percent at sea level at a Mach number of 1.2.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 2, 1955.

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Approved: Joseph A. Shortal
Joseph A. Shortal
Chief of Pilotless Aircraft Research Division

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1. Hughes, J. W.: Model F-101A - Measurement of Elastic Characteristics of the 10% Scale Aileron Rocket Models. Rep. No. 3676 (Contract No. AF33(600)-8743), McDonnell Aircraft Corp., Aug. 26, 1954 (revised Oct. 12, 1954).

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3. Strass, H. Kurt, and Marley, Edward T.: Rolling Effectiveness of All-Movable Wings at Small Angles of Incidence at Mach Numbers From 0.6 to 1.6. NACA RM L51H03, 1951.

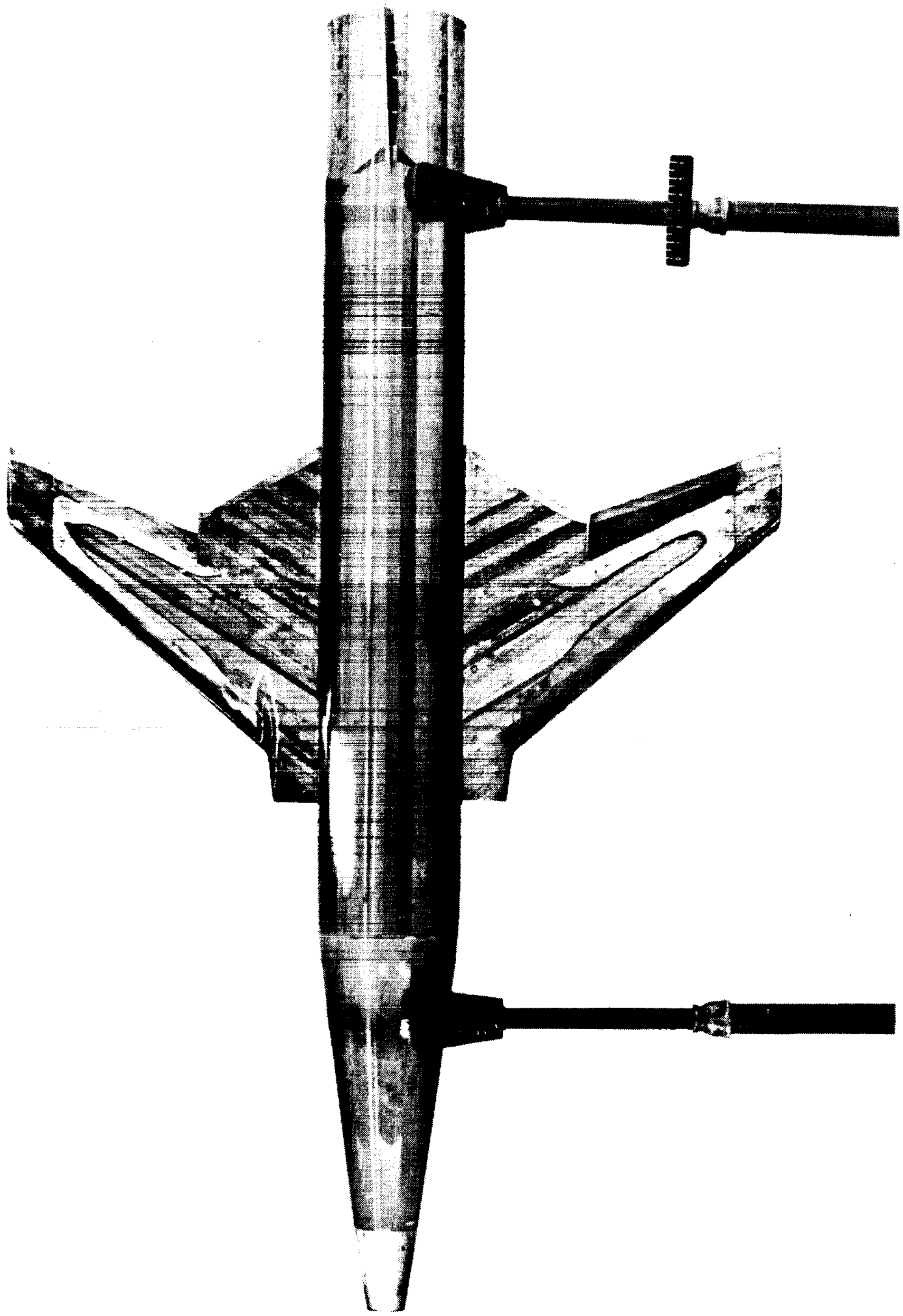

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Figure 1.- Photograph of typical model.

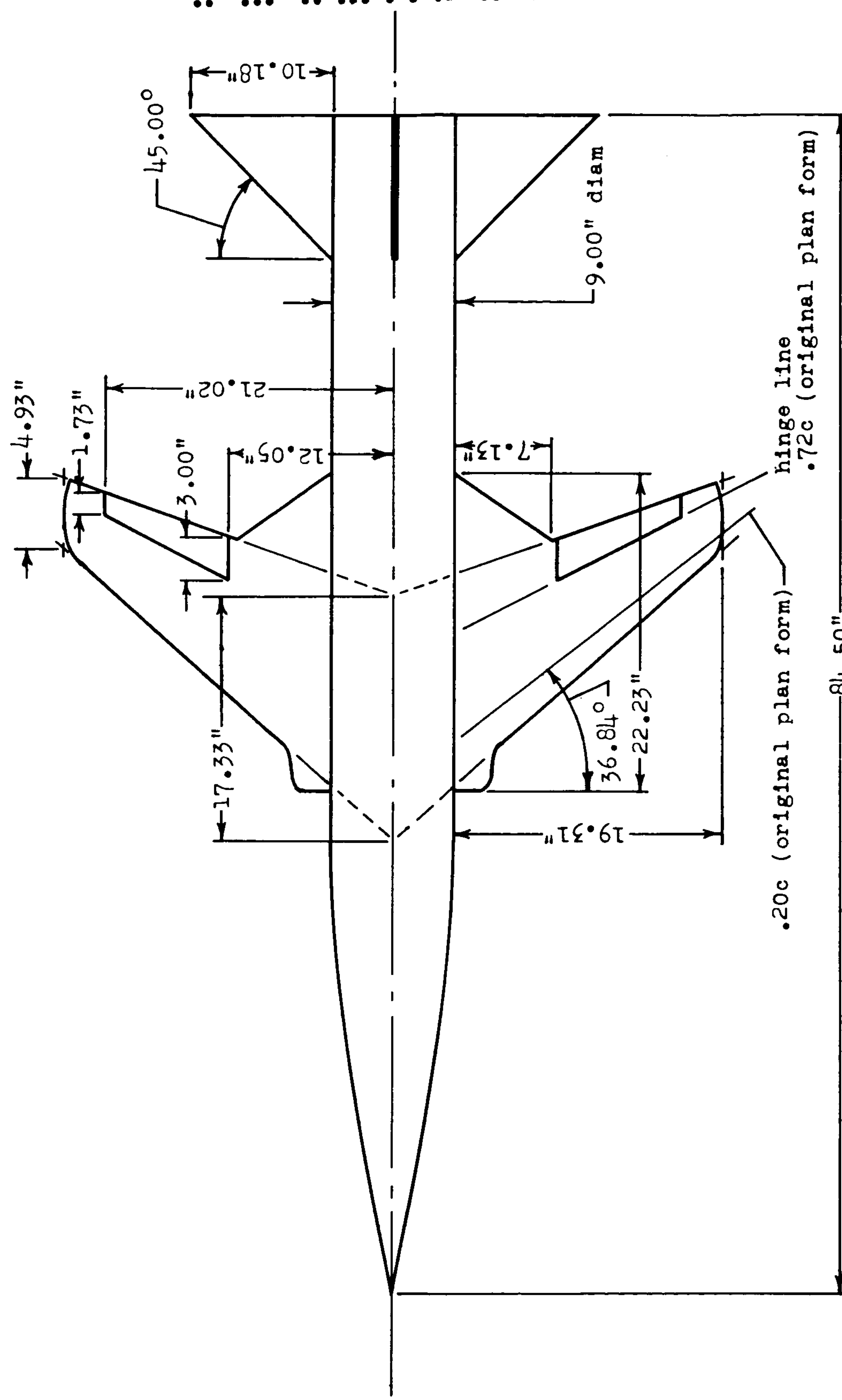
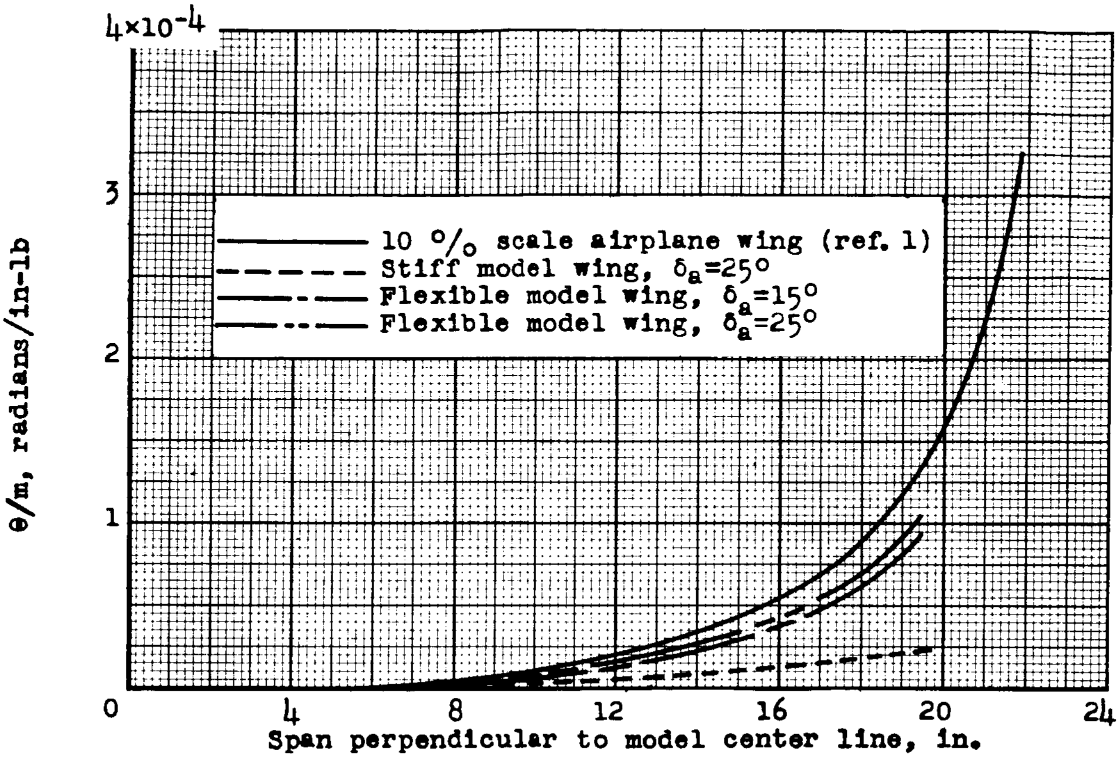


Figure 2.- Sketch of model configuration.



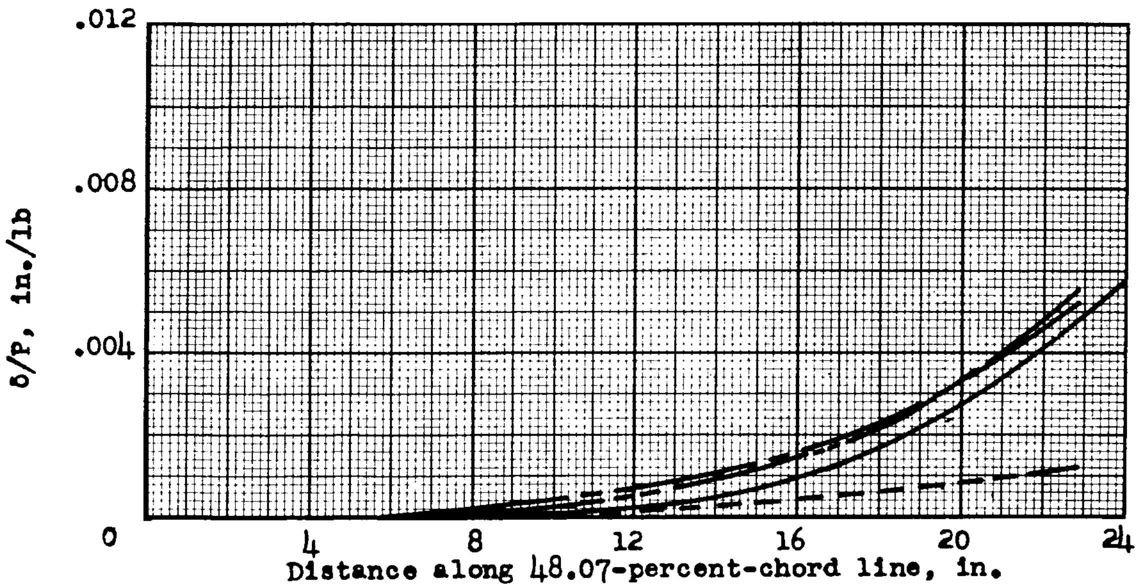


Figure 3.- Stiffness characteristics of model wings compared with scale stiffness of F-101A wing.

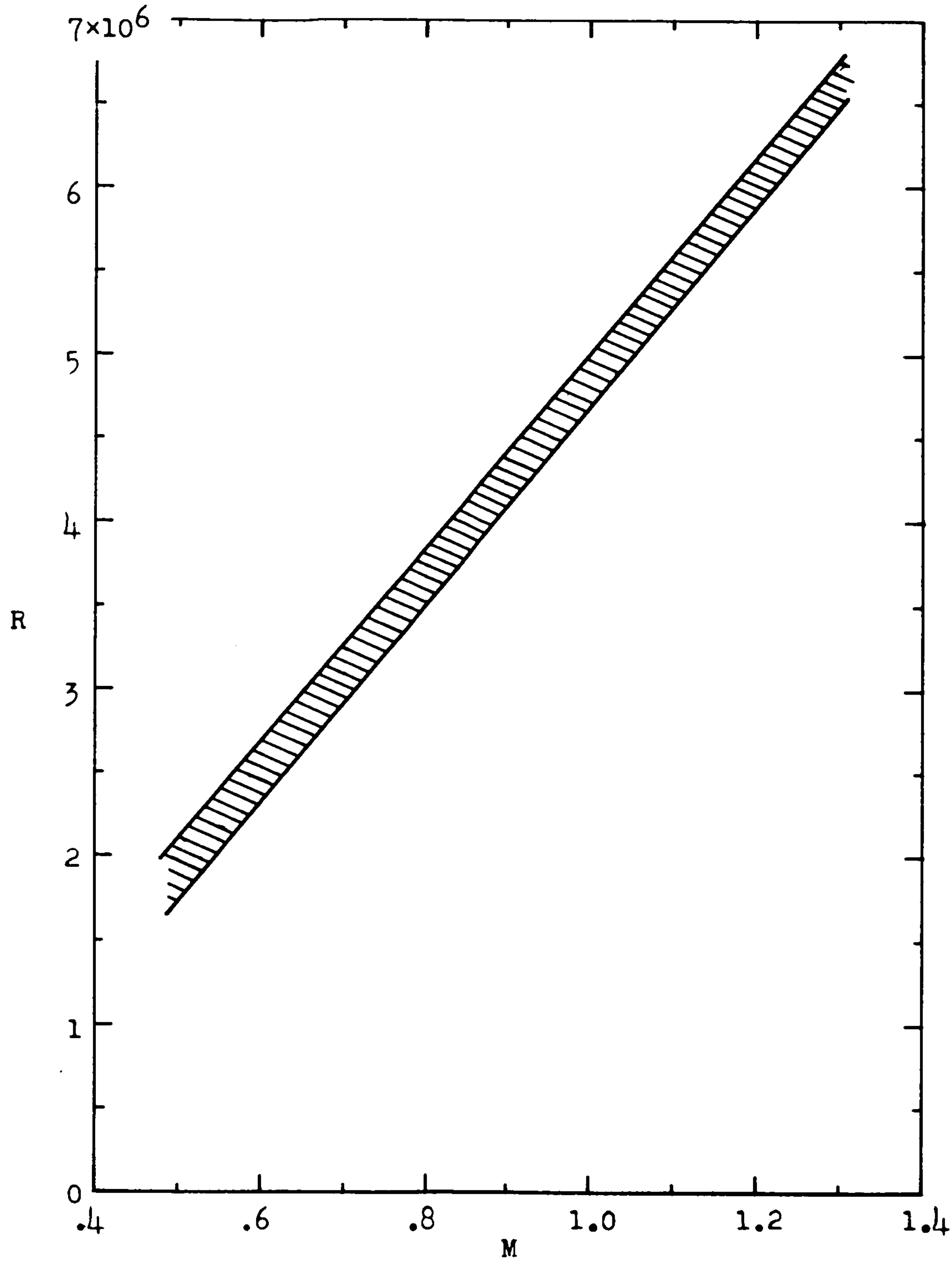


Figure 4.- Variation of Reynolds number with Mach number. Reynolds number based on wing mean geometric chord, 0.928 foot.

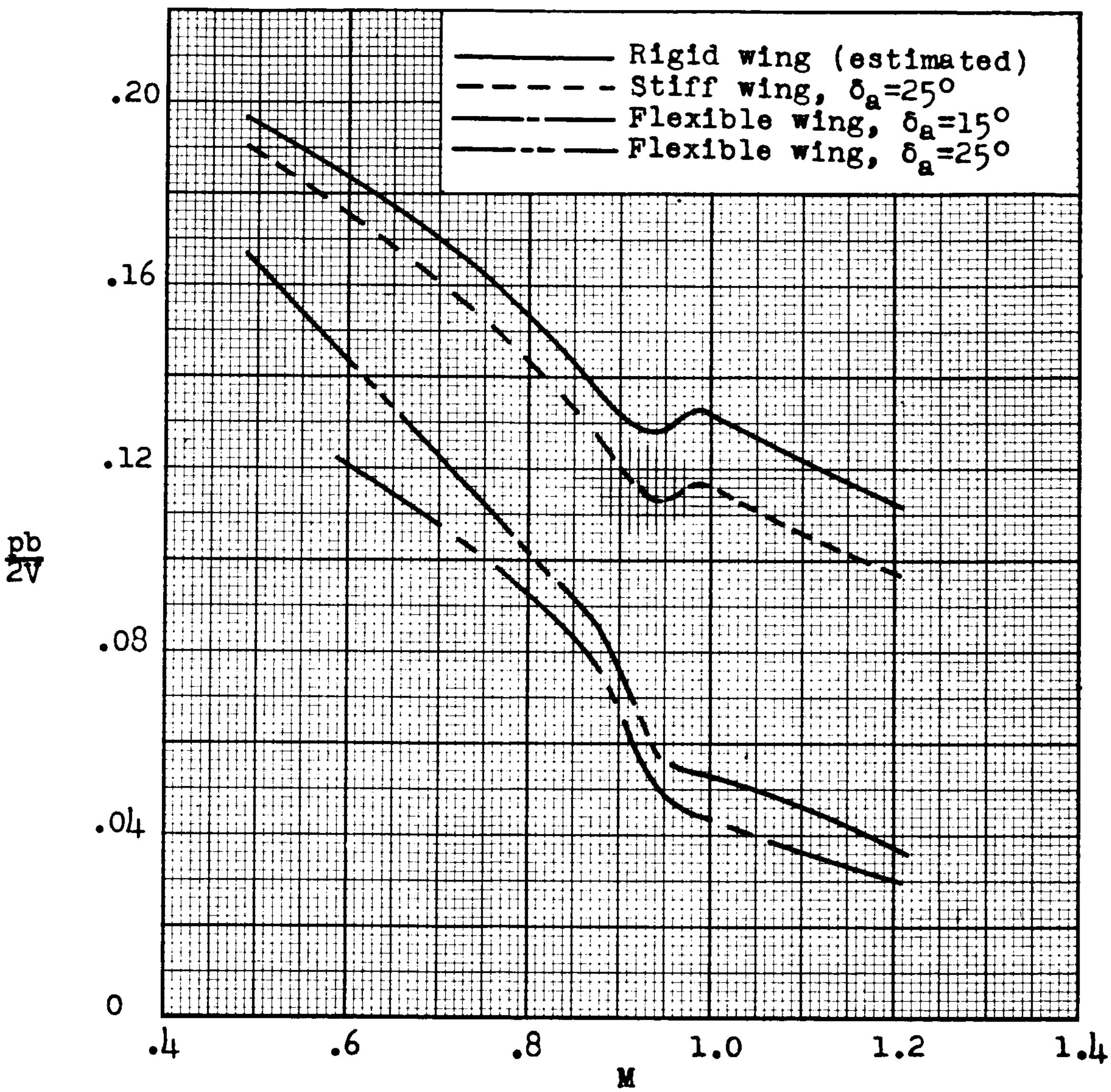


Figure 5.- Variation of rolling effectiveness parameter pb/2V with Mach number.

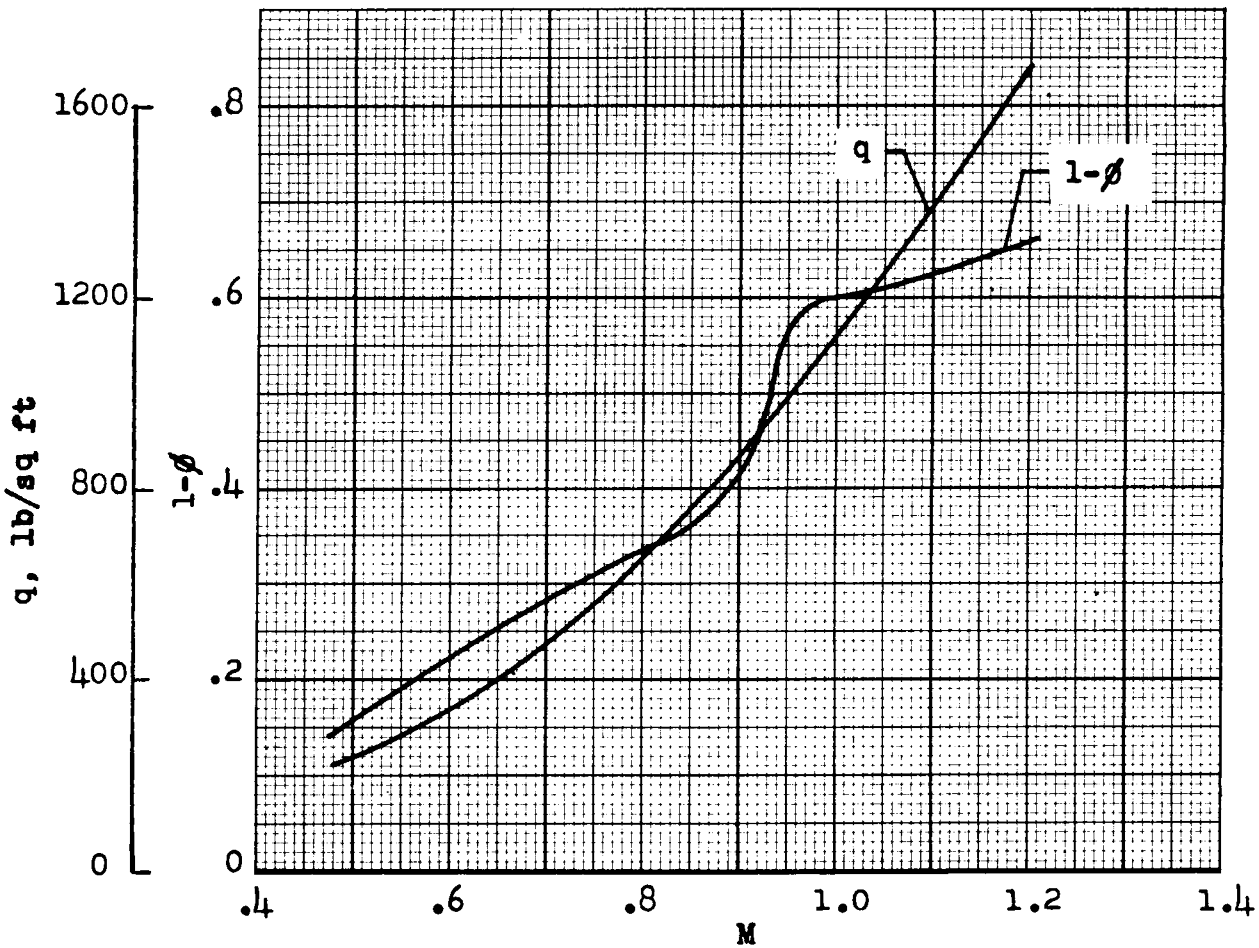


Figure 6.- Variation with Mach number of q and 1 - ϕ for the flexible-wing model with 25° aileron deflection.

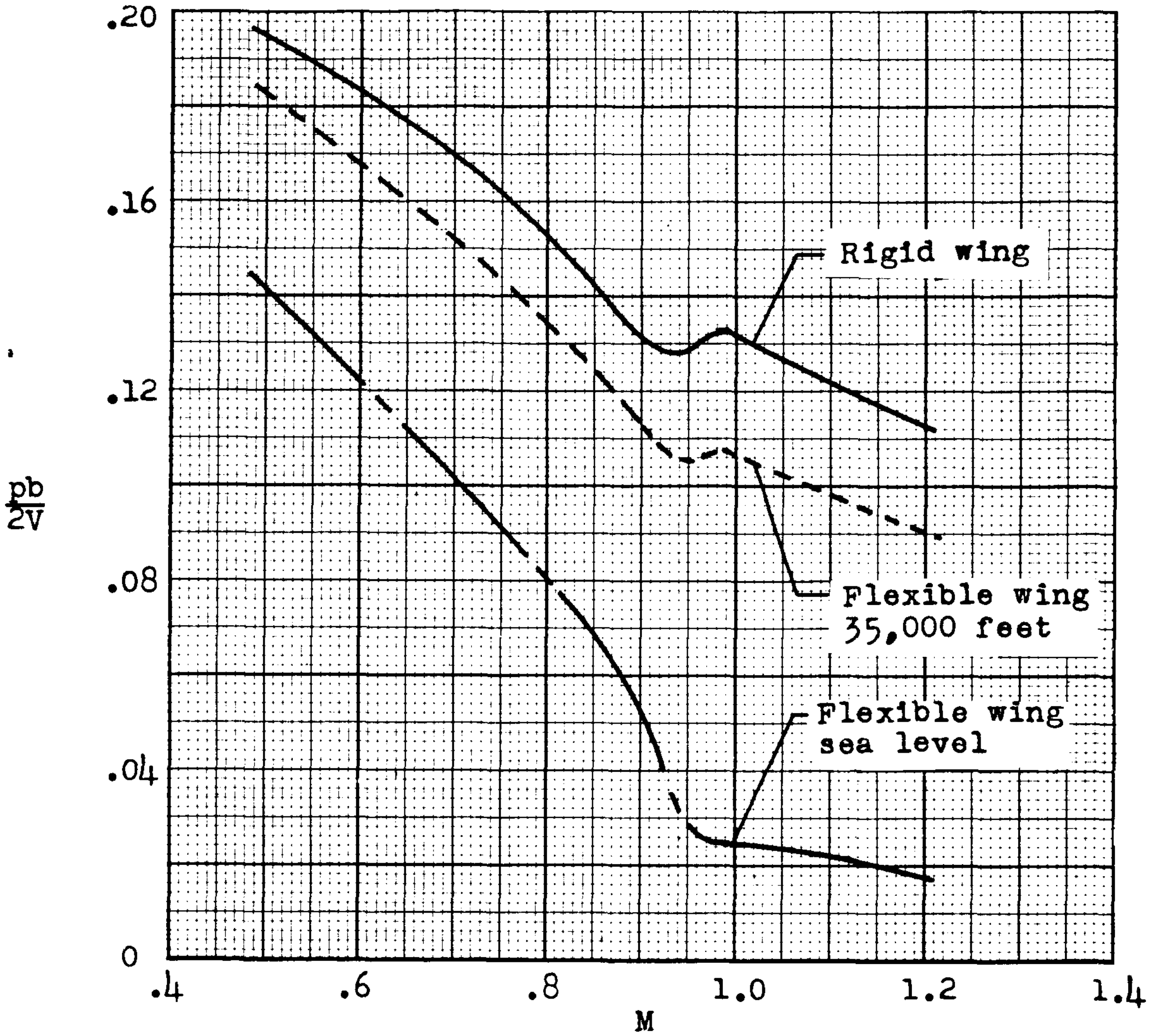


Figure 7.- Comparison of rolling effectiveness of the flexible wing at sea level and 35,000 feet with rigid-wing rolling effectiveness. $\delta_a = 25^{\circ}$.

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